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ABSTRACT

This paper describes the first phase of a study to investigate students' evaluations of computer laboratory modules in a university-level, non-majors biology course. The National Science Foundation-funded project has two primary goals: (1) to develop programmable, multifunctional Bio LabStations for data collection and analysis, lab extensions, simulations, and student assessment; and (2) to implement, evaluate, revise, and finalize a series of laboratory exercises under actual classroom conditions. Field observations of the labs and student responses to a written survey administered at the end of the first year of the project indicate: (1) the computer modules are helpful in understanding the lab because the students receive a strong visual/mental image of the experiment or simulation; (2) a general approval of using computers in the lab because computers are perceived to be a necessary component of modern science; and (3) strong preferences and dislikes for particular lab modules based on each module's perceived ease of use and the importance of the topic to the student. Appendices include a description of computer lab module activities, survey questions, and computer hardware and software used in Biology 110 and Biology 111 at Purdue University. Contains 21 references. (Author/JRH)

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EVALUATING COMPUTER LAB MODULES FOR LARGE BIOLOGY COURSES

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Abstract

This paper describes the first phase of a study to investigate students' evaluations of computer laboratory modules in a university-level, non-majors biology course. The NSF-funded project has two primary goals: (1) to develop programmable, multifunctional Bio LabStations for data collection and analysis, lab extensions, simulations, and student assessment, and (2) to implement, evaluate, revise, and finalize a series of laboratory exercises under actual classroom conditions.

Field observations of the labs and student responses to a written survey administered at the end of the first year of the project indicate (1) the computer modules are helpful in understanding the lab because the students receive a strong visual/mental image of the experiment or simulation, (2) a general approval of using computers in the lab because the computers are perceived to be a necessary component of modern science, and (3) strong preferences and dislikes for particular lab modules based on each module's perceived ease of use and the importance of the topic to the student.

EVALUATING COMPUTER LAB MODULES FOR LARGE BIOLOGY COURSES

Objectives

This paper describes the first phase of a study to investigate students' evaluations of computer laboratory modules in a university-level, non-majors biology course. We are interested in assessing students' attitudes about computers in general and their perceptions of computers as data acquisition tools and learning aids in particular. These modules were developed with support from the National Science Foundation to fund a research project entitled, "Innovative and Flexible Computer Lab Modules for Large Biology Courses" through the Instrumentation for Laboratory Improvement (ILI) program. The project is directed by Dr. Joseph W. Venable, Principal Investigator, and Drs. C. David Bridges and Mark E. Browning, Co-Principal Investigators, at Purdue University. The on-going NSF-funded project has two primary goals: (1) to develop programmable, multifunctional Bio LabStations for data collection and analysis, lab extensions, simulations, and student assessment, and (2) to implement, evaluate, revise, and finalize a series of laboratory exercises under actual classroom conditions.

As the evaluation team working with this project, we have had a set of general and specific objectives in mind as we have studied the effectiveness of the computer lab modules. The general evaluation goals are to examine students' reactions to the computer lab modules as learning tools by having students explain their perceptions of the advantages and disadvantages of the modules and whether and how the modules affected their learning. More specifically, the evaluation goal is to determine which of the computer lab modules used during the 1995-96 academic year in BIOL 110/111 were the most and least liked and students' reasons for these choices. This information can then be used to revise the existing lab modules and improve them for future use in these classes and in similar large biology courses.

Phase I of our evaluation involved data collection using written surveys completed by all students at the end of the 1995-96 academic year to evaluate their use of the computer lab modules in both BIOL 110 and BIOL 111. Our work during this phase focused on the development of the survey questions, analysis categories, and analysis procedures for the survey data. Subsequent phases of the evaluation will involve additional data collection via surveys and individual and group interviews of students, teaching assistants, and course instructors. This additional information would provide more in-depth information about the students' and teaching staff's evaluations of these computer modules, and allow us to better determine the extent to which the instructors' goals for these modules match with the students' and TAs' perceptions of the purpose and effectiveness of the modules.

Significance of the Study

The term 'technology' comes from the Greek *technologia* and literally means a systematic treatment of an art; therefore, technology is usually used in the sense of an applied science. In this study, we have operationally defined 'technology' as referring to the applied science of using a particular instrument to measure some property of a system under observation. We argue that various forms of technology convey different types and different levels of information about the system under observation. For example, a pH meter gives a series of numerical values for pH as a function of the amount of base added to an acid, and a computer-interfaced probe will build a real-time graph which represents the addition of the base to the acid. Both technologies accurately describe the same phenomenon, neutralization of the acid by the base, but the two technologies provide a different type of information and a different level of information about the acid-base system. Nakhleh and Krajcik (1993) reported that the specific type of technology used to perform standard acid-base titrations influenced students' thought processes and consequent understanding of acid-base chemistry. In the present study we examine the use of computer-based technology in a biology teaching laboratory to examine whether the various types of computer technology

available in this course affected students' understanding of the concepts embedded in the laboratory activities.

Technology should not drive the science curriculum, but technology, appropriately used, can contribute to learning in the lab by allowing students to do things that they could not have done before or to observe phenomena which were too transient to be clearly observed without the technology. Simulations and tutorials can also be helpful laboratory tools because they provide another pathway for students to review basic principles and construct understanding. In summary, technology can be a multi-purpose laboratory tool which helps students formulate hypotheses, test hypotheses, and collect and interpret data.

In the past, lab experiments in large, non-majors biology courses have provided little opportunity for hands-on experience, partly because of cost, and partly because appropriate experiments have never been developed. The Bio LabStations used in this study consist of simulations and various sensors and transducers (such as an oxygen electrode, pH electrode, strain gauges, pressure transducers, microphones, and recording and stimulating electrodes for electrical events) using Macintosh Power PC computers. The goal is to provide stimulating, hands-on laboratory experiences that can be presented using a common core of hardware and software. The concept of the Bio LabStations provides a flexible and innovative way to equip biology laboratories. It also employs a strategy that has led to striking gains in graphing skill (Stuessy & Rowland, 1989) and development of higher order thinking skills (Stringfield, 1994). Furthermore, by using the same basic equipment for a variety of laboratory exercises, students should be able to focus more on the goals and objectives of the equipment-based activity, and less on learning how to use the equipment (Nakhleh & Krajcik, 1993, 1994).

Several studies have found that computer-interfaced sensors, known as microcomputer-based laboratories (MBLs), enhance student involvement and understanding at the secondary and middle school levels (Nachmias & Linn, 1987), but little or no work has been done with university-level students. Therefore, information gathered in the course of evaluating this program will contribute significantly to the literature on science learning at the tertiary level.

Theoretical Perspective/Previous Work

We base our work firmly on the constructivist theory of learning (Wittrock, 1986; Osborne & Wittrock, 1983). We also believe that group interactions, particularly in the case of laboratory work, play an important role in an individual's construction of scientific understanding (Eichinger, 1993; Eichinger & Anderson, 1992; Eichinger et al., 1991). Yet another aspect of the social nature of learning science is inherent in the ways in which students are asked to demonstrate their knowledge of scientific phenomena, particularly in laboratory settings. As stated by Lee et al. (1993):

The social dimension of scientific understanding involves the ability to participate in activities that are characteristic of communities of scientifically literate people. In particular, members of these communities use specialized forms of language and action that enable them to describe, explain, predict, and control phenomena or systems in the world around them with precision and power. (p. 250)

Our theoretical perspective is that students create understanding from individual effort and peer interactions and that the laboratory can enhance this understanding when students make observations, collect data, and interpret their observations and data in an appropriate way.

A limited number of previous studies have examined the role of computer-based laboratory activities in helping students develop their understanding of science. For example, Nakhleh and Krajcik (1993, 1994) found that MBL substantially enhances learning even in such standard laboratory processes as acid-base titrations. This enhancement appears to involve the focusing of the student's attention upon the graph being constructed on-screen during the titration. Three factors seem to contribute to the effectiveness of MBL: the interactive, dynamic nature of computer-driven experiments, the immediate visual feedback of real-time graphing, and the freeing of a student's working memory to predict and speculate about phenomena (Mokros & Tinker, 1987; Nakhleh & Krajcik, 1993, 1994).

Beichner (1990) explored 237 secondary and college physics students' understanding of kinematics and motion graphs by comparing real demonstrations and computer simulations with MBL. Previous work by Brasell (1987) had indicated that MBL's effectiveness was attributable to the real-time, immediate nature of the MBL graphs generated in an experiment. Therefore, Beichner investigated whether or not the 'simultaneous perception of motion and graph' of this real-time event are the critical factors in effective learning. He developed a Videograph program which was essentially a simulation in that it showed a video of a motion event and simultaneously displayed a kinematics graph of that event. He then used a two by two design of Videograph vs. traditional lab (variable 1) and viewing a demonstration of a real motion event vs. not viewing the demonstration (variable 2). He assessed learning by a 24-item multiple-choice Test of Understanding Graphs--Kinematics instrument (KR-20 reliability of 0.71) administered pre/post. He reported no significant differences between the various groups, although the Videograph groups demonstrated greater gains on the test than the other groups. He concluded that simultaneous perception of motion and event is probably not the critical factor in the success of MBL; he hypothesized that the critical factor might be the ability to control the graph displayed by MBL by controlling the motion event itself. That is, students using MBL have the ability to change the conditions of the experiment and then to see how those changes affect the emerging graph. However, the literature on computer simulations is sparse, and our data on the Bio LabStation will contribute to this literature.

Science students at all levels appear to have difficulty integrating the concepts learned in the classroom with the procedures and experimental outcomes experienced in the laboratory (Nakhleh & Krajcik, 1993). They often find it difficult to integrate the macroscopic and microscopic levels of science with laboratory procedures, data analysis, and science concepts learned in lecture (Herron, 1983; Nurrenbern & Pickering, 1987; Nakhleh, 1993; Nakhleh & Mitchell, 1993). Students also seem to find the laboratory experience itself difficult (Nakhleh & Krajcik, 1993). First, the numerous procedures given in a typical laboratory experiment are confusing. Second, students often do not know what they are supposed to observe, so they concentrate on observing

irrelevant details. Third, by the time students start analyzing data, they may have forgotten much about the purpose of the experiment and how to interpret the data. These very real difficulties cause students to become discouraged and to decide that the laboratory has little relation to what is learned in the classroom or that it is not as important as the classroom material.

Recent research has also investigated race/ethnicity, gender, and social class differences in K-12 educational use of computers in terms of access, processes, and outcomes. Sutton (1991) summarized research conducted during the 1980s on these issues, and concluded that "the use of computers maintained and exaggerated inequities, that equity issues are complex and future research should reflect this, that between-school differences in equality should be examined, and that much more research on poor and minority children is a priority" (p. 475). While this review focused exclusively on the use of computers in elementary and secondary educational contexts, it is reasonable to suggest that these same issues are relevant at the post-secondary education level as well. Thus, one aspect of our data analysis involved investigating the possibility of differences in students' perceptions of the use of computer lab modules based on their gender.

Design and Procedures

The ILI grant described above provided funding for the development of computer-based laboratory modules for two large enrollment, non-majors' biology courses: BIOL 110/111, *Fundamentals of Biology*, and BIOL 203/204, *Human Anatomy and Physiology*. Total enrollment in these courses is approximately 1600 students per semester. The research described in this paper represents the development of evaluation instruments and data analysis procedures as the first phase of the complete evaluation program for the grant. The data reported in this paper represent a subsample of the total student population using the lab modules; specifically, the survey results are only from students in BIOL 110/111 during the 1995-96 academic year.

BIOL 110/111, *Fundamentals of Biology*, is a required course offered to Pre-Pharmacy and Agriculture students. The enrollment is approximately 850 students per semester in two sections of lecture and 40 two-hour sections of lab each week. BIOL 110/111 replaced *Biology of*

Plants and Biology of Animals, which had been offered for these students for many years. The courses were thoroughly revised two years ago by Dr. Venable, who upgraded the outdated audio-tutorial lab by creating a new two-semester sequence, *Fundamentals of Biology*, which focuses on principles of biology. One of the major objectives of the course revision was to develop a considerably more rigorous and quantitative laboratory experience than was previously available.

With support provided by the ILI funding from the National Science Foundation, a series of computer laboratory modules were developed for use in BIOL 110/111. These modules were meant to provide a variety of computer-based activities that required students to use the computers and associated technology for data acquisition, lab extension, and simulation activities. During the 1995-96 academic year, the students in BIOL 110/111 had access to computer-based labs in the following content areas: cell membrane permeability, chick embryonic development, electrocardiogram (EKG), the Hardy Weinberg law and gene frequencies in populations, nerve simulation, and population genetics. Each of these labs is briefly described in Appendix A.

To assess students' responses to the use of these activities, we developed a written survey in consultation with project PIs which included demographic information (gender, year in school, major, and computer experience), advantages/disadvantages of using computers in the lab, how the computer affected learning, and most/least liked computer experiments. The questions were asked using a combination of a five-point Likert scale (1 = strongly agree to 5 = strongly disagree) and free-response questions. We also observed the six computer labs which were implemented during the course of the year, and these observations also played a role in developing the survey. (See Appendix B for a copy of the survey questions.)

This survey was administered to all BIOL 110/111 students (n=626) following completion of a two-semester sequence of courses (1995-96 academic year), and the average Likert scale response was calculated for each of the scaled survey items. In order to detect any potential differences between male and female students' responses to these questions, male and female average responses were calculated for each Likert scale item, and t-tests were used to test for statistical differences between these two sets of responses.

In order to analyze students' answers to the free response questions, we went through a series of steps to develop a set of analysis categories (See Appendix C for a copy of the analysis categories). In step 1, each of the three authors independently coded a random selection of 20 surveys to identify the initial analysis categories. From this, we developed an initial list of 13 categories which we then used (in step 2) to independently code 100 surveys (25 common to all reviewers and 75 unique to each reviewer). We modified existing categories by merging and expanding, and we also added new categories as needed. We then met to check inter-rater reliabilities and to negotiate differences in coding schemes. For the 25 common surveys in step 2, the inter-rater reliability for free-response question #1 (advantages/disadvantages of computer labs) was calculated at 0.86. The inter-rater reliability for free-response question #2 (did/how computers affect learning) was found to be 0.83. Finally, we also tabulated students' responses to question #3 (most liked computer experiment and why) and question #4 (least liked computer experiment and why).

Findings

Likert scale survey responses.

Students were asked to respond to a series of eleven statements concerning use of the computer lab modules, using a scale ranging from 1 (strongly agree) to 5 (strongly disagree). The entire scale and set of statements is listed below:

[1]	[2]	[3]	[4]	[5]
AGREE STRONGLY	AGREE MILDLY	NEUTRAL	DISAGREE MILDLY	DISAGREE STRONGLY

Statement

- 8) Using the computer provided a new way to learn the material.
- 9) Using the computer allowed me to observe concepts that would be hard to see otherwise.
- 10) I liked using the computer because I could work at my own pace.
- 11) Using the computer was confusing for me.
- 12) The computer was not useful because I couldn't study from it.
- 13) Using the computer helped me to understand the purpose of the experiment.

- 14) Using the computer helped me to understand the ideas covered in the experiment.
- 15) Using computers is important in a modern science course.
- 16) The data displayed by the computer help me to make sense of the experiment.
- 17) I would rather *not* use computers in the laboratory.
- 18) Data collected using the computer are more accurate than data collected by other means.

Tables 1, 2, and 3 report the results of students' responses to these statements, showing overall mean responses, mean responses for female students, and mean responses for male students. These results are discussed below, first for the entire data set, and then for the male and female responses separately.

Whole data set. In looking at the responses of all students to Statements 8-16 in the survey, three patterns emerged. First, the responses on Statements 8-10 and 14-16 were clustered in Categories 1 and 2 (Agree Strongly and Agree). Students' responses to Statements 8-10 indicated that they thought the computer provided a new way to learn the material (S8), allowed them to observe otherwise difficult concepts (S9), and allowed them to work through the material at their own pace (S10). The responses also indicate that the students found that the computers helped them understand the experiment (S14), and they agreed that computers are important in modern science courses (S15). Students also indicated that the data display helped them understand the *ideas* covered in the experiment (S16).

Second, Statements 13 and 18 elicited favorable responses (Categories 1 and 2), but a sizable group of students also were neutral to the statements (Category 3). Students thought that the computer helped them understand the *purpose* of the experiment (S13) but 127 students were neutral in their opinion on this statement. Students also indicated a general belief that data collected by computers are more accurate than data collected by other means (S18), but again a sizable group of students were neutral to this statement. This response to Statement 18 may mean that many students do not realize that computer-generated data is subject to the same scrutiny and interpretation as data collected by any other means. Therefore, course instructors may need to explicitly address this issue early and often in the lab.

Third, students disagreed with three of the statements (S11, S12 & S17). Students disagreed that the computer was confusing (S11), and they disagreed that the computer was not useful because they could not study from it (S12). They also disagreed with the statement that they would rather not have computers in the lab (S17). These disagreements generally support the favorable view of computers reported in the other survey questions; however, we note that in each of these three statements, a sizable number of students were neutral in their response. Therefore, we compared the male and female responses by gender to see if these trends were similar for each gender group.

[Insert Table 1 - All Student Responses to Likert Items about here]

Comparisons by gender. In comparing the male and female responses to Questions 8-16 in the survey, two basic observations can be made. Males and females exhibited the same direction of responses in all statements except Statement 11 (Using the computer was confusing to me). This statement has an interesting distribution because 70.2% of the females and 66.6% of the males disagreed (Categories 4 and 5) that the computer was confusing. However, we note that almost one-third of the males and females fell in the remaining categories. We interpret this finding to mean that the students had varying levels of computer expertise and that about a third of the students are not very comfortable with computers. Therefore, instructors in the course will need to address this differential computer expertise.

An analysis of t-tests between males and females on Statements 8-16 showed no significant differences in the responses of both groups except for Statements 8 and 14. In both statements, females agreed significantly more than the males that computers provided a new way to learn the material (S8) and that they understood the ideas of the experiment better using the computer (S14). We interpret these data to mean that both genders find the computers helpful and that females may derive more benefit than males in some instances.

[Insert Table 2 - Female Responses to Likert Items and Table 3 - Male Responses to Likert Items
about here]

In the demographic information for this survey, students were asked to indicate their major area of study and their class rank. A preliminary analysis of the mean responses to Statements 8-16 indicates no real differences by major or by class rank. Therefore, we next analyzed the free response questions on the survey to confirm or disconfirm the trends noted in the analysis of Statements 8-16.

Free-response survey questions #1 and 2. Question #1 asked students to discuss the advantages and disadvantages of using computers in the laboratory. Table 4 shows the number and percentage of responses that were classified in each analysis category. Categories 1 (Visual/Mental Picture) and 2 (Flexibility) account for more than 30% of the students' responses. Students strongly indicated that an advantage of the computer is that it helped them construct a visual and/or mental picture of the experiment, and they also appreciated the ability to work through the experiment in a flexible manner, i.e. repeat procedures and proceed at their own pace. These results are very consistent with the results found in the statistical analyses reported above. Category 5 (Clarified concepts) also accounted for more than 12% of student responses. Students felt that the computer lab modules made ideas clearer, and helped them better understand and remember the ideas being taught in the lab activities. Again, these results support students' responses to the Likert scale items. Other categories frequently mentioned as advantages of the modules were Category 3 (Computer experience), Category 9 (Time issues), and Category 12 (Accurate data). Students' positive responses in Category 3a (5.0%) indicated that doing computer-based labs provided valuable experience in how to use and become more comfortable with computers as science laboratory tools. Students' positive responses in Category 9b (5.8%) revealed that students felt the computer lab modules took less time to complete than traditional labs. Category 12 (7.1%) also revealed that students felt that using computer lab modules provided more

accurate data and permitted less room for experimental and/or human error than if the data had been collected by other means. These results confirm the results reported for Statement 18 in the Likert items.

Categories #3 and #9 also revealed that some students felt using the computer lab modules was a disadvantage. In Category 3b, some students (2.6%) expressed a dislike for using computers, and others (1.6%) felt that students who were inexperienced in using computers would have trouble completing these labs (Category 3c). A small percentage (1.6%) of responses to item #9 showed that some students felt that using computers was a disadvantage because it took more time than doing lab activities without computers (Category 9a).

Question #2 asked students whether using the computer labs affected their learning of the lab material, and if so, to explain how it did. Once again, students' responses indicated that the visual/mental imagery was important in their learning (Category 1 = 23.2%). They also clearly indicated that the computer affected their learning because it helped them clarify their understanding of the lab (Category 5 = 32.7%). Interestingly, some of the students indicated that the computer did not affect their learning, by simply writing the word "No" as their answer to Question #2. We are not sure whether this means the computers had no effect or whether students felt the computers had an adverse effect. Recent versions of the survey have been designed to more accurately distinguish students' neutral from their negative answers to this question. Additional information about this will also be collected via interviews during future phases of the project evaluation.

Free-response survey questions #3 and 4. Questions #3 and #4 asked students to indicate and comment on the most liked and least liked of the six computer experiments. (See Table 5 for a summary of students' responses to these questions.) By far the most liked experiment was the fruit fly genetics simulation (69.1%). Students commented that this computer module provided an "overview", a "clearer picture", and a "clearer explanation" of a topic which many of them found confusing and difficult. They also enjoyed the ability to quickly generate many generations of fruit flies and to actually 'see' the outcomes of the crosses. Students also felt that this simulation

provided more accurate results and was less difficult than doing actual crosses with living *Drosophila*.

The Hardy-Weinberg experiment and the Chick Embryonic Development simulation were the least liked experiments. Students gave reasons such as "long", "confusing", or "boring" for experiments they did not like. For the chick embryonic development activity, many students had a hard time visualizing the perspective being presented by the computer graphics, and misunderstood the computer "fly-through" as representing different stages of development of a single portion of the embryo rather than a series of successive images from different areas of the embryo at a single point in time. Finally, several students noted that they disliked the "fly-through" because it was too abstract, only involved looking at the computer screen, and did not involve any manipulation or hands-on work with the images or with an actual specimen.

Interestingly, even the heavily favored fruit fly genetics simulation had some detractors; conversely, the least liked experiments had a fair number of students who favored them. At this point, we hypothesize that a Vygotskian "zone of proximal development" phenomenon may be in effect here (Vygotsky, 1978). An experiment might be perceived favorably if students know enough to appreciate the complexity of the topic and/or they perceive the topic to be important in their personal lives or career. In other words, there must be a degree of cognitive readiness before full benefit can be derived from an experiment, whether it is presented as a computer lab module or in other formats.

Implications

As indicated in the discussion of the results presented above, our initial evaluation of the use of computer lab modules in a large biology class has identified some strengths and weaknesses of these types of activities. The survey, with multiple question formats, consistently revealed that the visual pictures provided by the computer, the flexibility in the use of labs in this format, and the improved understanding of the concepts presented in these labs were cited by many students as strengths of the computer lab modules. The primary weakness seemed to be that, unless students

feel they have sufficient familiarity with and fluency in using computer-based activities, they will not be able to fully benefit from the potential advantages provided by this instructional format.

Consistent with the overall goals of the NSF-funded project, it is important to note that the results of this first phase of evaluation provided the course instructors with valuable evidence and impetus for modifying the computer lab modules. In particular, analyses of students' answers to the free response survey questions about the most and least liked labs and their reasons for their selections revealed important sources of misunderstanding and misinterpretation of the concepts being presented. This information led to revisions in the lab modules and clarification of the conceptual and procedural objectives of the activities. Thus, the development and implementation of appropriate data collection tools and analysis procedures for the survey information have supported the usefulness of computer lab modules for most students while at the same time identifying areas for improvement.

Phase I of this study was based only on written survey results. Given the limitations of these data sources and results, we recognize the need to develop additional data collection procedures and analyses to further explore students' and instructors' evaluations of these activities. In Phase II of our evaluation study we plan to collect additional data via individual and/or group interviews with students, teaching assistants (TAs), and course instructors to further elaborate on students' perceptions of the effectiveness of computer-based labs, and to investigate the extent to which students' perceptions of the usefulness of labs correspond to TAs' and/or instructors' perceptions and goals.

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TABLE 1 - ALL STUDENT RESPONSES TO LIKERT ITEMS

Statement	1	2	3	4	5	SUM	MEAN
8	319	246	41	11	5	622	1.61
9	294	245	58	18	8	623	1.72
10	290	228	76	20	9	623	1.76
11	20	74	102	190	235	621	3.88
12	30	89	155	167	181	622	3.61
13	149	312	127	31	4	623	2.08
14	193	323	81	22	4	623	1.91
15	288	245	71	15	3	622	1.71
16	205	300	83	24	9	621	1.92
17	21	40	102	179	275	617	4.05
18	156	209	206	35	7	613	2.23

TABLE 2 - FEMALE RESPONSES TO LIKERT ITEMS

Statement	1	2	3	4	5	SUM	MEAN	S. D.
8	176	122	19	5	1	323	1.55	0.704
9	156	126	31	8	2	323	1.68	0.796
10	159	116	34	10	4	323	1.71	0.867
11	10	43	43	103	123	322	3.89	1.149
12	16	53	71	89	94	323	3.59	1.205
13	75	168	67	11	2	323	2.06	0.794
14	102	181	33	5	2	323	1.84	0.714
15	155	121	40	4	3	323	1.70	0.804
16	106	157	46	10	3	322	1.90	0.820
17	9	21	49	99	143	321	4.08	1.053
18	74	119	107	15	2	317	2.22	0.879

TABLE 3 - MALE RESPONSES TO LIKERT ITEMS

Statement	1	2	3	4	5	SUM	MEAN	S. D.
8	143	124	22	6	4	299	1.68	0.806
9	138	119	27	10	6	300	1.76	0.898
10	13	112	42	10	5	300	1.82	0.911
11	10	31	59	87	12	299	3.87	1.129
12	14	36	84	78	87	299	3.63	1.158
13	74	144	60	20	2	300	2.11	0.874
14	91	142	48	17	2	300	1.99	0.867
15	133	124	31	11	0	299	1.73	0.791
16	99	143	37	14	6	299	1.95	0.907
17	12	19	53	80	132	296	4.02	1.118
18	82	90	99	20	5	296	2.24	0.989

**TABLE 4 - FREQUENCY AND PERCENTAGE OF STUDENT RESPONSES TO
FREE RESPONSE QUESTIONS #1 AND #2**

ANALYSIS CATEGORY	FREE RESPONSE QUESTION #1		FREE RESPONSE QUESTION #2	
	# OF STUDENT RESPONSES	% OF STUDENT RESPONSES	# OF STUDENT RESPONSES	% OF STUDENT RESPONSES
1	213	18.2	131	23.2
2	142	12.1	32	5.7
3a.	58	5.0	7	1.2
3b.	31	2.6	5	0.8
3c.	19	1.6	1	0.2
4	42	3.6	16	2.8
5	141	12.1	185	32.7
6	34	2.9	11	2.0
7	57	4.9	21	3.7
8	43	3.7	16	2.8
9a.	19	1.6	2	0.4
9b.	68	5.8	15	2.7
10	47	4.0	5	0.8
11	48	4.1	4	0.7
12	83	7.1	7	1.2
13	14	1.2	9	1.6
14	65	5.6	70	12.4
MISC.	46	3.9	28	5.0
TOTAL	1170	100.0	565	100.0

**TABLE 5 - FREQUENCY AND PERCENTAGE OF STUDENT RESPONSES TO
FREE RESPONSE QUESTIONS #3 AND #4**

Experiment	FREE RESPONSE QUESTION #3 (MOST LIKED LAB)		FREE RESPONSE QUESTION #4 (LEAST LIKED LAB)	
	# of Responses	% of Responses	# of Responses	% of Responses
Cell Membrane Permeability	2	0.4	26	7.2
Chick Embryonic Development	65	13.2	130	36.1
EKG	25	5.1	30	8.3
Hardy- Weinberg	39	7.9	100	27.8
Nerve Simulation	21	4.3	28	7.8
Genetics Simulation	340	69.1	46	12.8
TOTAL	492	100	360	100

APPENDIX A - DESCRIPTION OF COMPUTER LAB MODULE ACTIVITIES

1. Cell Membrane Permeability (BIOL 111) - In this activity students use a variety of solutes (e.g., NaCl, urea, glycerol, glucose, butanol, and propanol) to determine their rate of diffusion across a red blood cell membrane. Cell lysis while in an isotonic solution of a particular molecule indicates penetration of that molecule, and the time needed for hemolysis to occur is an indication of the rate of diffusion of that molecule. Students use computers as data acquisition and analysis instruments to determine rates of diffusion.
2. Chick Embryonic Development (BIOL 110) - This simulation is designed to give students a more concrete picture of the abstract notion of the morphology of embryonic development. The simulation consists of digital movies. Each frame of the movie is a digital photograph of a cross-sectional slice from a preserved chick embryo. The first frame is taken from the head of the embryo and the last from the tail. Several hundred cross sections were progressively cut from a preserved chick embryo and photographed. Then the pictures were electronically compiled into a digital movie that allows students to "fly-through" the embryo. Students examine chick morphology at two developmental stages: 33 hours and 48 hours. They are able to stop the movie and make sketches of the stages at any time.
3. Circulatory Physiology /EKG (BIOL 110) - Students use the computers as data acquisition and analysis tools for measuring the electrical activity of their own heart. They use surface electrodes to record their own EKG, measure their heart rate, and record blood pressure measurements.
4. Hardy Weinberg and Gene Frequencies (BIOL 110) - While it is possible to convey the mathematics of the Hardy-Weinberg Equilibrium in lecture, it is more difficult to convey in a quantitative way the effect of small gene pools (genetic drift) and of having selection operating from one generation to the next as mating occurs. This activity uses a computer tutorial on the Hardy-Weinberg Equilibrium and a simulation to allow students to change the size of the gene pool and to impose all degrees of selection during "mating," so that the consequences of non-random mating seen in small gene pools and the consequences of selection on gene frequencies in many successive generations can be quickly plotted for them.

5. Nerve Simulation (BIOL 111) - To help students learn what makes neurons irritable, this activity uses a computer simulation to discover some properties of nerves. This is done by simulating a nerve in a chamber containing a representation of a frog sciatic nerve set between two electrodes. One set of electrodes stimulates the nerve and the second set, which is hooked up to an oscilloscope, records signals sent along the nerve fiber. Students measure the effects of temperature on nerve conduction, and measure the time required for ether (an anesthetic), tetrodotoxin (a sodium channel blocker), and ouabain (a Na/K pump poison) to have their effects on nerve conduction velocity.
6. Population Genetics of *Drosophila* (BIOL 111) - Students work with an electronic version of *Drosophila* that simulates the genetic behavior of this organism in order to explore monohybrid crosses, dominance, and dihybrid crosses. Students select particular traits to be followed through multiple generations of crosses and are able to "see" the results of these crosses in a short amount of time.

Evaluation of Computer Use in the Laboratory for BIOL 110 & 111 and BIOL 203 & 204

This survey is part of a NSF-supported effort to study new ways of teaching and learning biology at the university level. We are seeking your input as to how we can best reform the teaching of undergraduate biology! Your answers are very important to us, and we appreciate your time and effort. Your opinions expressed here will be very helpful to us in designing future undergraduate biology courses. By returning this survey, you are giving us permission to use your information as part of our data. Thank you in advance for your help!

Record your answers to the following on the beige opscan sheet.

- 1) I am [1] Female [2] Male
- 2) I am a [1] Freshman [2] Sophomore [3] Junior [4] Senior [5] Other
- 3) I am currently enrolled in the following school:
 [1] Agriculture [2] Engineering [3] HLS [4] SLA [5] Science [6] Other
- 4) *During the 1995-1996 academic year, I was a student in (check all that apply):*
 [1] BIOL 110 [2] BIOL 111 [3] BIOL 203 [4] BIOL 204
- 5) *In these courses, I have used computers for the following purposes (check all that apply):*
 [1] Tutorials [2] Simulations [3] Word Processing [4] Data Base
 [5] Spreadsheet [6] Data collection in lab
- 6) *Other than these courses, I have used computers for the following purposes (check all that apply):*
 [1] Tutorials [2] Simulations [3] Word Processing [4] Data Base
 [5] Spreadsheet [6] Data collection in lab [7] I have never used a computer outside of these courses
- 7) In the past year, how many *hours per week* would you estimate that you use a computer?
 [1] less than 1 [2] 1-2 [3] 3-4 [4] 5-6 [5] 7 or more

Please select the response on the beige opscan sheet that most accurately describes your opinion. Respond to questions 8-18 using the answers shown immediately below.

[1]
AGREE
STRONGLY

[2]
AGREE
MILDLY

[3]
NEUTRAL

[4]
DISAGREE
MILDLY

[5]
DISAGREE
STRONGLY

Statement

- 8) Using the computer provided a new way to learn the material.
- 9) Using the computer allowed me observe concepts that would be hard to see otherwise.
- 10) I liked using the computer because I could work at my own pace.
- 11) Using the computer was confusing for me.
- 12) The computer was not useful because I couldn't study from it.
- 13) Using the computer helped me to understand the purpose of the experiment.
- 14) Using the computer helped me to understand the ideas covered in the experiment.
- 15) Using computers is important in a modern science course.
- 16) The data displayed by the computer helps me to make sense of the experiment.
- 17) I would rather *not* use computers in the laboratory.
- 18) Data collected using the computer are more accurate than data collected by other means.

For the following courses, indicate below the experiments in which you used the computer:

BIOL 110-111

- ☐ Hardy-Weinberg
- ☐ Nerve Stimulation
- ☐ Chick Development Fly By
- ☐ EKG Experiment
- ☐ Cell Membrane Permeability Experiment
- ☐ Genetics Simulation

BIOL 203-204

- ☐ EKG Experiment
- ☐ XXX
- ☐ XXX
- ☐ XXX
- ☐ XXX
- ☐ XXX

1. In your opinion, what are the advantages and/or disadvantages of using computers in the biology laboratory?

2. In your opinion, did using the computer affect the way in which you learned the material? If so, how did the computer affect your learning?

3. Which computer experiment did you like MOST and why?

4. Which computer experiment did you like LEAST and why?

**APPENDIX C: FREE RESPONSE ANALYSIS CATEGORIES FOR
QUESTIONS #1 AND #2**

Q. #1

Q. #2

- 1. Visual/Mental Picture**
 - A. See what's happening
 - B. Made a picture of what I was studying
 - C. Easier to visualize the experiment
- 2. Flexibility**
 - A. Repeat procedures
 - B. Go at my own pace
- 3. Computer experience**
 - A. Understand Macs (technology/computers) better
 - B. Don't like computers
 - C. Inexperienced have trouble using computers
- 4. Novel way to learn (change of pace)**
- 5. Clarified concepts (non-specific)**
 - A. Made things clearer
 - B. Understood things better
 - C. Remember things better
- 6. Better/more detailed instructions**
- 7. Difficult to study for exams**
- 8. Not hands-on/not a real experiment**
- 9. Time issues**
 - A. Negative - Takes too much time
 - B. Positive - Takes less time/saves time
- 10. Confusing/vague (generally)**
- 11. Difficult experiment can be done**
- 12. Accurate data/No experimental errors/
Allows greater precision**
- 13. Tangible/Hands-on experience**

14. Non-specific

- A. Easier/smoothier
- B. Helped a lot
- C. More organized than other methods
- D. Keep everything cleaner
- E. More interesting/enjoyable

APPENDIX D: Computer Hardware and Software used in BIOL 110 and BIOL 111 at Purdue University

Current Hardware

Twenty PowerPC Macintosh 7100/80, each equipped with a 15 inch color monitor, 2X speed CD ROM drive and 1.44 MB floppy drive. Each machine has 40 MB of RAM, a 700 MB hard drive, and 3 NuBus expansion slots. All utilize system software 7.5.1.

Each Macintosh is equipped with a National Instruments LabNB data acquisition board.

Three of the Macintoshes are also equipped with an AV card capable of digitizing video. (One machine has only an Apple AV card; the other two have the Apple AV card augmented by a SuperMac SpigotPower AV card that enhances the frame capture rate. We have not yet had need for the higher frame capture rate as we have only captured still frames from a video camera mounted on a microscope.)

We use a Nikon LABOPHOT-2 trinocular microscope and a JVC color video camera (model TK-128OU) to capture still video images from prepared slides.

We use EKG signal conditioners that were custom-built by the Purdue University Department of Biological Sciences instrument shop. (The department has 10 of these signal conditioners.) The signal conditioners amplify the tiny EKG signals and optically isolate the patient from the computer hardware.

(Initially, we had only 10 of Macintoshes listed above and 8 LabNB boards. This proved inadequate. Survey results were gained while we had only 10 machines.)

Current Software

All applications used by students in lab were developed in-house.

Instrumentation (EKG) software was developed with National Instruments LabVIEW.

Simulations were developed in MacroMedia Director (*Drosophila* Genetics) or LabVIEW (Hardy-Weinberg and Nerve [Compound Action Potential]).

We use one tutorial (Hardy-Weinberg) that was developed with Director.

We have QuickTime (digital video) movies of 33-hour and 48-hour chick serial cross sections, termed "fly-throughs." (The movies allow for dynamic inspection of internal features of developing chickens. They are used in conjunction with whole mount slides that afford an exterior view of the embryos.)

(The software listed above was in use when the first survey was done.)

Our microscope slide identification aids were developed with a shell originally built in Director. These aids contain digitized versions of prepared slides that have interactive labels. They help students orient themselves to slides and identify parts of specimens. So far we have digitized slides of frog embryos, chick embryos, monocot roots and stems and dicot roots and stems. Students interact with the digitized slides before looking at the real things. All test questions are based upon actual, not digitized, slides.

(The microscope identification aids were added to the software already in use when the second survey was done.)

Near Future Software

We will use a Biological Diversity Browser next fall that was developed in Director.

Next spring we will use Spec 20's, the LabNB boards and LabVIEW software in our cell membrane permeability and enzyme labs to record and analyze optical density data.

Mid Future Software

We will develop the hardware and LabVIEW software that will enable us to acquire, display and analyze data from an oxygen probe inserted into a culture of illuminated cyanobacteria.

FOR MORE INFORMATION CONCERNING THE HARDWARE AND SOFTWARE
DESCRIBED ABOVE, PLEASE CONTACT:

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